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Studying and Generation of Saffron Flower's 3D Solid Model

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Abstract

Because of having non-rigid parts in various and complicated shapes and high level of variability in their shapes, plants have remained one of the most difficult objects to be modeled. Saffron is the most expensive agriculture crop and spice in the world. There is very few information about physical and geometric properties of Saffron flower. In this article, using reverse engineering, 3D data of Saffron flower are extracted by using laser scanner, and after data processing, using some techniques and algorithms, the 3D model of Saffron flower was developed.

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Keywords: laser scanner; reverse engineering; geometric modeling; Saffron flower; virtual flower.

1. Introduction

Saffron is the most expensive agriculture crop and spice in the world [1]. Saffron can be propagated from the spherical part known as corm of Saffron (Fig. 1). Saffron Flower is made from three parts including petal, anther and stigma. The most important part of the flower is the red part with 25-30 millimeters length which is known as commercial saffron [2]. Saffron gives natural taste and color to food and has medical and industrial properties too. However, its high price is a barrier for extensive use of it in all fields. Iran, by producing 170 Tones Saffron or about

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81 percent of world production, is the biggest producer of this crop in the world [3]. Today, harvesting and post-harvesting of Saffron is carried out manually. Mechanization of these processes not only decreases the final price of the crop but also is highly important in terms of hygienic.

Nomenclature

3D	Three-dimensional
2D	Two-dimensional
mm	millimetre
μm	micro-metre
Kg	kilogram

Geometric modelling of Saffron flower has not been carried out before. There is very few information about physical and geometric properties of Saffron flower and its parts. In addition, regarding few studies on mechanization of post-harvesting process of this crop, an accurate study of the subject has been impossible that is due to the lack of a virtual model. By making a 3D model, not only physical and geometric parameters of flower is provided, but also a more accurate aerodynamic study of the object will be possible. Geometric modeling of such natural objects as flowers, as they are composed of various parts including petal, stem and pistil with different shapes, is one of the most difficult modeling. Given complexity in shape and diversity of the flowers, and also, because of their flexibility, it is very important to provide a suitable method for geometric modeling of them. There are few methods in which these various changes in flowers and plants are explained. Plants modeling include structure modeling and geometric modeling [4].

A. Lindenmayer in 1968 proposed a mathematical model for explaining the different changes in multi-cell plants [5]. This method, known as l-system, completed after him and used for modeling many plants and trees [7, 8]. In this algorithm, the focus is on structure and shape of the plants and geometric modeling is not the main goal of this theory [6]. In this method, complicated objects are revised, using simple parts and using a set of specific signs and rules. Thus, this method is considered to be a rewriting method. This algorithm was developed by P. Prusinkiewie in Calgary University and used extensively for plant modeling. L-system was a suitable method of plant modeling and today there is many different usage of this method. However, when geometric and accurate modeling of plants is the subject of matter, this method is useless [9]. For modeling object, sufficient information and knowledge of l-system language is required.

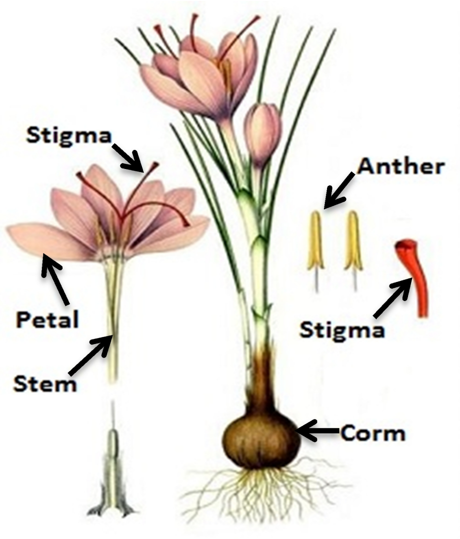

Fig. 1. Various Component of saffron flower.

Sketch-based modeling is a simple and quick method of plant modeling. Modeling is carried out based on floral diagrams and inflorescences of them [10]. Flower diagrams are specifying layout of flower (petal, sepal, anther, etc.) and inflorescences indeed specifies the order of each flower in the set. This method of modeling contains two separate parts including structure modeling and geometric modeling [4]. Every part has editorial environments for making structure and geometry of plants. T. Ijiri et.al. (2005) used this method for modeling various plants [10]. This method is also known as Ijiri method. Zh. Ding et.al. (2008) also used a method similar to Ijiri method for modeling rigid flowers [4]. Limitation of Sketch-based modeling is in making different shapes of flower parts. For example, only elliptical petals can be created [10], and it has no application in high accuracy 3D modeling [9].

Modeling plants, especially by using synthetic curves, is the other method of geometric modeling of plants. Synthetic curves, because of having some properties, are considered a suitable designing tool to meet the different limitations in shape such as preserving continuity and curvature. Requiring synthetic curves is more felt in two main cases. First, when the curve is defined by many measured points of the object. This method has many applications in reverse engineering. Second, is when the curves made in the first stage of the design, need to be changed and edited to provide requirements of the design. In both cases, we require curves that have relationship with specified points and have sufficient flexibility for movement, rotation or changing shape using control points [11]. Zh. Ming et.al (2009), using NURBS curves, modeled cotton [12]. This method has been used to measure size of leafs, their diameter and stem while the plant grows. Cotton parts were modeled by a 2D method, but creating a 3D model has not been done in this area. X. Wang. et.al (2011), using B-Spline curves, modeled leaf of plants to evaluate the amount of growth in them [4]. Geometric modeling consists of two parts; veins modeling and leaves surface modeling. In addition, thickness of leaf was considered in this method.

Using photographs taken of the object is a semi-automatic technique in reconstruction of 3D model. In recent decade, according to the new developments such as non-invasive imaging technique and image analysis, a good opportunity has been provided for more accurate studies and access to phenotypic information [13]. One of these methods is to use 2D photos in reconstructing 3D model of plants, by using industrial application cameras. L. Quan et.al (2006) used this method to reconstruct the 3D model of plants [14]. In this method, at first, different photos of object are taken from different views and then 3D point cloud is extracted. In next step, each component of the plants is separately modeled using 2D photos and 3D data. Modeling plants with high complexity and special structures is difficult by this method [13]. 3D scan method was introduced by Paproki et.al (2012) [15]. They, using digital photos taken from different views, modeled the cotton plant with stem and a few large leaves. However, there was already the problem of reconstructing 3D model of plants with complex structure [13]. In comparison with digital photography, laser scan method provides straightforward ability of making 3D points-cloud based on spherical structure with non-destructive method. In this study, using non-contact Reconstruction with laser scanning, point clouds were extracted. Because of having the possibility to scan the object from various views and due to the high quality level of laser scanning system, this method is suitable for modeling plants with complex structures. After processing, using software and algorithms, the extracted point clouds are used for reconstructing 3D model.

2. Materials and methods

2.1. Laser scan system

The used laser scan system includes laser scanner installed on one base (Fig. 2), rotary table and control unit. Using blue light, the scanner (COMET LED-2M, Steinbichler, Germany) is able to take very high quality images. It has the ability of scanning parts with up to 16 million point in less than 2 seconds. Measuring field of scanner is $100 - 400$ mm and up to 60 μm resolution (Point to point distance) can be achieved. For small and medium parts up to 30 Kg weight, we can use rotary table. Rotary table is very important in automatic and uniform data acquisition. Control unit is notebook PC that is used to store and manage information.

Fig. 2. COMET LED Laser Scanner.

2.2. Saffron flower

Autumn is the season of harvesting saffron flower. Harvesting period is about 40 days. Time of harvesting is early morning before sunrise. For 3D modeling of Saffron flowers, they must be harvested in suitable time. To this end, in November 2013 the flowers were collected in bud to prevent withering while scanning. Because of the fast withering in saffron flower, scanning process must be carried out as fast as possible. Also, owing to the flexibility of flower components and changes in its status, a suitable fixture should be used to fix it to the scanner.

2.3. Reconstructing 3D Model of saffron flower using laser scanner

Reconstructing 3D model of saffron flower by using raw primary data obtained from scanning, involves several different processes (Fig. 3). First, primary point cloud of every component of saffron flower (petal, stem, anther and stigma) are extracted. Second phase consists of uniform making of point cloud. Then, after separating and resolving the interference in point cloud (petal), all components of flower will be meshed and surfaced. In final phase, using some techniques and algorithms the components of flower will be jointed, and the integrated model of saffron flower will be developed.

2.3.1. Laser scanning

Because of non-rigidity and flexibility of saffron flower and scanning of hidden components including anther and stigma, there is no possibility for integrated scanning of flower. Therefore, every component of flower must be scanned individually. A suitable fixture was used to maintain the status of components of flower during the scan process. Scanning process was done through scanning the object from its different surrounding perspectives. Scanning process was carried out automatically and the results were extracted and stored as a set of 3D geometric (x, y, z) points, which define the point cloud of the object.

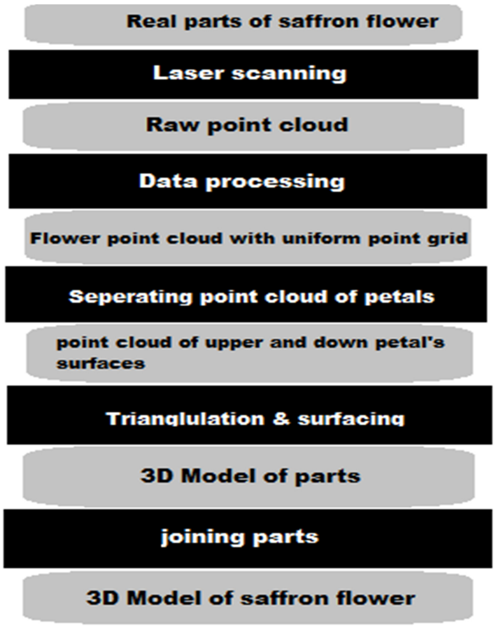

Fig. 3. Dataflow chart of the multiple step process of reconstructing saffron flower's 3D model using laser scanner.

2.3.2. Data processing

Processing of point cloud involves separating point cloud of components of saffron flower from other parts including fixture and other added parts around the object that is scanned. Scanning has been done automatically and in different angles. Therefore, the scan rate is uniform and extracted point cloud is a regular grid of 3D points. The distance between a point and the next point equals 60 μm. Then, using specified algorithms, these data undergo noise reduction and elimination process to remove the noise.

2.3.3. Separation of point cloud of up and down of petal surfaces

Saffron flower has fine and thin petals. Thickness of its petals is not fixed and the farther we get from the stem to the tip of petal, the petals thickness decreases. Thickness of petal varies depending on the zone of planting and type saffron corn. Because of the very low thickness of the petals, the extracted point clouds are interfering, and it is not possible to detect the up and down surfaces of the petals by using reverse engineering software. To create 3D model of the petals, the point cloud provided by scanner must be separated. To this end, an algorithm was proposed based on separating surfaces and normal vector of the point cloud. There are various methods for calculating the normal vector [16]. Choosing the neighborhoods of a point will affect the results of calculating the normal vector. In this study, to obtain the normal vector of cloud point, the homogeneous neighborhood method was suggested for calculating the normal vector. because this method, compared with K nearest neighbors method, has lower error in estimating the normal vector. After calculating the normal vector of point cloud, the direction of normal vectors of the points in one side is equal. Thus, the up and down points on the surface of the petal point cloud will be separated. Fig. 4 shows how our method works.

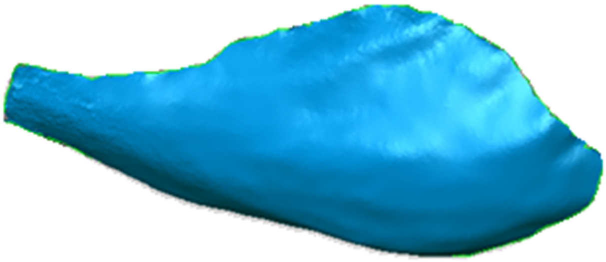

Fig. 4. Modeling of petal after using proposed algorithm

2.3.4. Meshing and surfacing

For extracting geometric parameters and 3D modeling of saffron flower, first, each component of flower will be meshed and then surfaced. To this end, commercial and practical software in the field of reverse engineering was used. In each phase of modeling, different software with more capability than others was used for modeling. For example, in this study, for making and editing mesh and surfacing two different software were used. By making 3D model of different components of flower, their geometric parameters also will be calculable.

2.3.5. Joining different components of saffron flower

Because of non-rigidity and flexibility of saffron flower and scanning of hidden components including anther and stigma, we separated the components of flower and individually scanned every component and made 3D model of different components include petal, stem, anther and stigma. Now we need to join different components to make the 3D integrated model of saffron flower. We have a set of boundary points to join petals to stem, which are common in two components and were continuously positioned in the area of separating petal and stem. Therefore, through specifying the boundary points in petals and stem, they will be joined. Normally, saffron flower has six petals. Therefore, first, given the places where separation has been done before, we put petals on stem. Now, through considering the joining (include putting the component to its real position) components in continuous style and using common boundary points in point cloud of petals and stem, the process of joining petals to stem will be carried out. After joining point cloud of petal and stem, using the previously mentioned tools and algorithms, meshing and surfacing will be done. The position of stigma in saffron flower is exactly in the middle of stem. Anthers of saffron flower are also positioned in center of the flower and around the stigma. Various software tools of reverse engineering were employed for positioning these components.

3. Results

After completing various processes on raw data obtained from the laser scanner, 3D model of saffron flower different components was created (Fig. 5). To extract geometric parameters of every individual component of flower 3D model of every part have to be created separately. By joining various components of saffron flower, the integrated rigid 3D model of saffron flower was developed (Fig. 6). Point cloud separation and the problem of interference in point cloud of the petals were developed in saffron flower. Petals of saffron flower are fine and their thickness is very low and variable. Therefore, detecting its different surfaces is impossible by using different software of reverse engineering. This problem addressed in this study, and using the introduced algorithm, the separation of up and down surfaces of petal was developed. In order to solve this problem, we used normal vector for separating points of data. To calculate normal vector, using homogeneous neighborhood was suggested. By using this method the average error value in estimation of normal vector is reduced compared with k nearest method, and the volume of calculations will be decreased in many aspects.

Point cloud extraction of hidden components (stigma and anther) is one of the existing problems in modeling flowers. This problem also addressed in this study and 3D model of hidden components of saffron flower was developed (Fig. 5.d and Fig. 5.c).

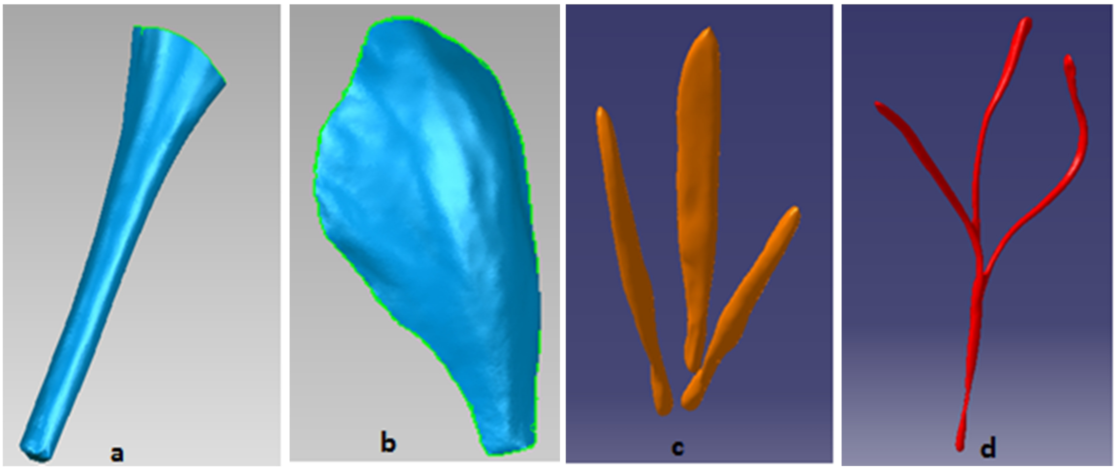

Fig. 5. 3D model of different components of saffron flower. (a) 3D model of stem after meshing and surfacing; (b) 3D model of petal after separating point clouds, meshing and surfacing; (c) 3D model of anther after meshing and surfacing; (d) 3D model of stigma after meshing and surfacing.

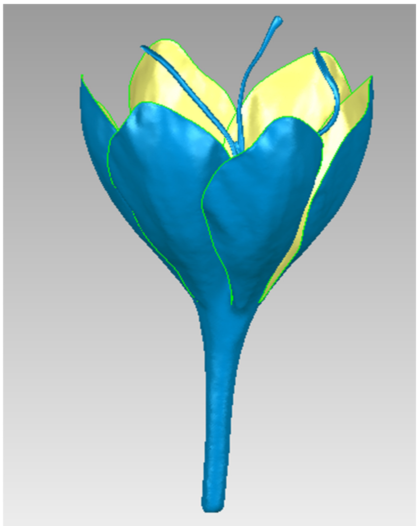

Fig. 6. 3D solid model of saffron flower.

4. Conclusions

In this study the 3D rigid simplified model of saffron flower was created. It was for the first time that the geometric modeling of saffron flower was performed. Although the rigid modeling leads to some limitations and for full modeling of the flower its flexibility must be considered. But this process is highly complicated and basic (rigid) modeling is fundamental in understanding the problems and considerations of full modeling. Although modeling methods, used for modeling plants have solved many problems, they are not suitable for an accurate modeling. Owing to the high accuracy of laser scanner system, it is highly suitable in explaining the details and problems of biology and agronomy. Using this system obtaining 3D information and various geometrical parameters of flowers and plants is possible in very high accuracy, and thus, it is suitable for accurately modeling plants. High accuracy of laser scanner gives us the opportunity of evaluating the growth of plants in different cycles. In this study, an algorithm was proposed for separating point cloud in objects with very low thickness. This algorithm is usable in separating data in different plants and with very low thickness. Modeling very tiny and complex objects is one of the problems in reverse engineering. The proposed algorithm may have various applications in reverse engineering.

References

[1] Babaie A, Abdollahpoor SH, Mahmoudi A, Fattahi S.H. Saffron Stigma Separation by Oscillating Seperator and Wind Tunnel. Canadian Center of Science and Education 2012;6:101-113.

[2] Khalili Kh. Simulation of falling saffron flower and the effect of acting forces on flowers orientation. Proceeding of the 26th iasted international conference. Modelling, Identification and Control. Austria: Innsbruck; 2007.

[3] Emadi B. Separating saffron flower parts using vertical air column. World Academy of Science, Engineering and Technology 2009;25:17-20.

[4] Ding Zh, XU S.C, YE X.Z, Zhang Y, Zhang S.Y. Flower solid modeling based on sketches. Journal of Zhejiang University SCIENCE A 2008;9:481-488.

[5] Lindenmayer A. Mathematical models for cellular interaction in development. Journal of Theoretical Biology 1968;18:280–315.

[6] Prusinkiewicz P, Lindenmayer A. The Algorithmic Beauty of Plants. Hanan J. S, Fracchia F. D, Fowler D. R, de Boer M. J. M, Mercer L. New York: Springer-Verlag; 1990. P. 1-30.

[7] Prusinkiewicz P, Karwowski R, Lane B. The L+C plant-modeling language. J. Vos *et al,* editors. In *Functional-Structural Plant Modelling in Crop Production*. Netherlands: Springer, Dordrecht; 2007.

[8] Prusinkiewicz P, Shirmohammadi M, Samavati F. L-systems in Geometric Modeling. 12th International Workshop on Descriptional Complexity of Formal Systems 2010;31:3-14.

[9] Wang X, Li L, Chai W. Geometric modeling of broad-leaf plants leaf based on B-spline. Mathematical and Computer Modelling 2011;58:564–572.

[10] Ijiri T, Owada S, Okabe M, Igarashi T. Floral diagrams and inflorescences: Interactive flower modeling using botanical structural constraints. ACM Transactions on Graphics (TOG) -Proceedings of ACM Siggraph 2005;24:720-726.

[11] Sederberg T.W. Computer Aided Geometric Design. Brigham Young University Department of Computer Science. United States: Provo, Utah; 2007.

[12] Ming Zh, Juan Y, Xiaoshuan Zh. Geometry Modeling for Cotton Leaf Based on NURBS. Wseas transactions on information science and applications 2009;6:1615-1624.

[13]Paulus S, Schumann H, Kuhlmann H, Le´on J. High-precision laser scanning system for capturing 3D plant architecture and analysing growth of cereal plants. Biosystems Engineering 2014;121:1-11.

[14]Quan L, Tan P, Zeng G, Yuan L, Wang J, Kang S. Image-based Plant Modeling. ACM transactions on graphics (TOG) - Proceedings of ACM siggraph 2006;25:599-604.

[15]Paproki A, Sirault X, Berry S, Furbank R, Fripp J. A novel mesh processing based technique for 3d plant analysis. BMC Plant Biology 2012;12:63.

[16]Foorginejad A, Khalili K. Using homogeneous neighborhood in point clouds normal vector calculation. Journal of mechanical engineering of modares, 2014;5:155-163.